THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

JUNE, 1954

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Page

General

Chemical Polishing: Review of Recent Developments 101
Bibliography on Electropolishing 101

Nickel

Flash-Smelting of Concentrates from Nickel-containing Ores 101
Refining of Nickel by the Carbonyl Process 101
Process for Production of Nickel Powder 101
Thermal Diffusivity of Nickel 102
Influence of Porosity on Thermal Conductivity of Nickel: Conductivity of Nickel Oxide 102
Effect of Hydrostatic Pressure on Curie Points of Nickel and Nickel Alloys 102
Magnetic Characteristics of Thin Single-Crystal Nickel Films 102
Measurement of Magnetostriction in Nickel and other Metals 102
Nickel in Depth-Recording Device 103
Sub-Zero Electrical Properties of Nickel Films 103
Metal Film Catalysts 103
Nickel-Alkaline Batteries in Marine Service 103
Nickel Compounds in Rubber 104
Electrical Properties of Nickel Oxide 104

Electrodeposition and other Coating Methods

Fourth International Conference on Electrodeposition and Metal Finishing: Discussions 104
International Progress in Electrodeposition 104
Nickel-Chromium Plating of Automobile Parts 104
Plating by Thermal Decomposition of Volatile Metal Compounds 105
Production of Nickel-plated Piping for Atomic-Energy Plant 105
Plating of Lead- and Tin-base Alloys 105
Nickel-Phosphorus Coatings: the 'Niphos' Process 106
Estimation of Boric Acid in Nickel-Plating Solutions 106
Determination of the Thickness of Bright-Nickel Coatings by the Jet Test 106
German Specifications for Electrodeposited Coatings 107
Chemical Methods for Determination of Thickness of Electrodeposited Nickel Coatings 107
Porosity Testing of Coatings on Zinc-base Die Castings 108

Non-Ferrous Alloys

Nickel-Copper Compensation Alloy 108
Copper-Nickel Alloy ThermocoupleWire 109
Young's Modulus of Nickel-Aluminium and Nickel-Copper-Zinc Alloys 109
Welding of 90-10 Copper-Nickel Alloys 109
Ordering Reactions in Nickel-Chromium Alloys: Electrical-Resistivity Studies 110
Effect of Radiation on Order-Disorder Changes in Nickel-Manganese Alloys 111
Copper-Nickel-Palladium Alloys 111
Nickel-Magnesia Cermets 111

Page

Nickel-Iron Alloys

Transformations in Nickel-Iron and Nickel-Iron-Carbon Alloys 111
Deformation of Austenite in Nickel-Iron Alloy during Martensitic Transformation 111
Mechanical Properties of High-Purity Iron-Nickel Alloys 112
Magnetostriction in Ferromagnetic Nickel-containing Materials 112
Ageing Phenomena in Magnet Alloys 112

Cast Iron

Magnetic and Electrical Properties of Cast Iron 112
Ni-Hard Cast Iron: Reference Data 113

Constructional Steels

Segregation Phenomena in Nickel and Chromium-Nickel Steels 113
Quantitative Assessment of Temper Embrittlement 114
Determination of Case Depth in Steels 114

Heat- and Corrosion-Resisting Materials

Investment Casting of Nickel-Chromium-base Alloys 114
Elevated-Temperature Properties of Steels containing Chromium and Molybdenum 114
Oxidation Characteristics of Nickel-Chromium Alloys 114
Nickel-Magnesia High-Temperature Coatings 115
Nickel-containing Alloys in Marine Engineering 116
Hard-Surfacing Materials in the Ceramic Industry 116
Prevention of Cracking in Austenitic Weld Metals 117
Spectrochemical Control in Stainless-Steel Production 117
Formation of Martensite in Austenitic Chromium-Nickel Steels 117
Shell-Moulding of Stainless Steel 118
Extrusion of Stainless and Heat-Resisting Steels 118
Manufacture of Stainless-Steel Tubing 118
Machining of Stainless Steels: Recommended Procedure 118
Heat Transfer at Sodium/Stainless-Steel Interface 119
Nickel-containing Materials in P. & O. Liner 'Arcadia' 119
Hydrogen Absorption by Austenitic Steels during Cathodic Loading 119
Effect of Potential on Corrosion-Resistance of Nickel-Chromium-Steel 120
Stainless Steel Bellows 120
Chromium-Nickel Steel Tubes for Welding: B.S. Specification 121

VOLUME 27 NUMBER 6

THE MOND NICKEL COMPANY LTD • SUNDERLAND HOUSE, CURZON STREET, LONDON, W.1
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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Chemical Polishing: Review of Recent Developments

R. PINNER: 'Theory and Practice of Chemical Polishing. A Survey of Solutions and Processes for Various Applications.' *Electroplating*, 1954, vol. 7, Apr., pp. 127–31, 140 (to be continued).

This article is part 3 of the series begun in the November and December 1953 issues of this journal: see *Nickel Bulletin*, 1954, vol. 27, No. 1, p. 2.

In opening a discussion of the theory of chemical polishing, the author deals briefly with metal dissolution in acid media, and describes various types of film growth. The importance of such films in suppressing etch attack is emphasized.

Two types of chemical polishing solution are distinguished: (1) those in which the dissolution rate is under diffusion control, and (2) processes characterized by slow dissolution in dilute solutions of low viscosity, in which brightening on a micro scale is obtained, e.g., by periodic formation and dissolution of oxide films.

Attention is directed to the importance of studying the behaviour of metals in nitric acid, since this acid is a main constituent of most solutions used for the chemical polishing of many metals and alloys. In this connexion the reactions of nitric acid and copper are discussed.

Bibliography on Electropolishing

'Bibliography on Electropolishing.' *Product Finishing*, 1954, vol. 7, Apr., pp. 59–62.

It is pointed out that in practically all the industrial countries of the world electropolishing is being increasingly used, in order to reduce labour costs involved in manual polishing, and to obtain improved surface finish. The chief commercial applications of the method are briefly reviewed, with illustrations of some parts typical of those for which it is employed. The main content of the paper is a *bibliography* of articles on electropolishing published since 1947. The compilation has been made for the Production Engineering Research Association.

Investment Casting of Nickel-Chromium-base Alloys

See abstract on p. 114.

NICKEL

Flash-Smelting of Concentrates from Nickel-containing Ores

'International Nickel Company's Flash-Smelting Process.' *Jnl. of Metals*, 1954, vol. 6, Apr., pp. 416–17.

The article recapitulates the essential sections of *U.S. Patent* 2,668,107, which covers the flash-smelting of concentrates from sulphide ores. Comment is made on the revolutionary nature of the process and on the economic benefit secured by its use, in place of conventional smelting methods. Sulphur dioxide recovered from the furnace exit gas (after cleaning, condensing, and cooling) is used in commercial production of sulphite wood pulp.

Refining of Nickel by the Carbonyl Process

'Improvements in Nickel Refining and the Manufacture of By-Products at Clydach.'
Industrial Chemist, 1954, vol. 30, Apr., pp. 167–71.

The refining of nickel by the (Mond) carbonyl process has previously been described in detail, both in this journal and elsewhere. This article deals solely with improvements and changes in procedure which have been introduced during the past fifteen years. Particulars are given of modifications in the extraction and refining processes; the new producer-gas and water-gas plants; wet methods for treatment of residues; the chemical-salts department, in which 34 varieties of nickel and cobalt salts are produced; the copper liquor plant, in which carbon monoxide of specially high purity is made for treatment of the nickel-containing calcined matte, and the pressure plant, in which iron and nickel powders are made.

Process for Production of Nickel Powder

F. A. FORWARD: 'Production and Properties of High-Purity Nickel Powder.' *Bull. Inst. Metals*, 1954, vol. 2, May, pp. 113–16.

This paper, read before the London Local Section of the Institute of Metals in November 1953, gives an account of an extraction process developed as the result of collaboration between Sherritt Gordon Mines, Ltd., and Professor Forward, at the University of British Columbia, Vancouver, Canada. The process is to be employed on a commercial scale in the Sherritt Gordon nickel refinery at Fort Saskatchewan, Alberta, which started operation early in 1954. Its essential features are ammonia leaching of the nickel-containing concentrate, followed by hydrogen reduction. The reactions involved in both stages are described.

It is claimed that the powder product (which can be obtained in varying and controllable particle sizes) is of a high purity: cobalt 0·10, iron 0·01, sulphur 0·01, copper less than 0·005, per cent., with only spectrographic traces of lead and no detectable amounts of carbon, zinc, arsenic, antimony, or other impurity. The character of the powder produced at various stages in the hydrogen-reduction cycle is shown by a series of photomicrographs, and data on typical apparent densities, particle size, etc., are tabulated. It is anticipated that the powder may be used, *inter alia*, for sintered battery plates, as an alloying medium, for producing nickel salts, and for rolling to sheet.

Thermal Diffusivity of Nickel

P. H. SIDLES and G. C. DANIELSON: 'Thermal Diffusivity of Metals at High Temperatures.'
Jnl. Applied Physics, 1954, vol. 25, Jan., pp. 58–66.

The authors describe a modified Ångstrom method for measuring thermal diffusivity, and hence thermal conductivity, of metals, and give results of measurements on copper, nickel, and thorium, over the temperature range 0°–500°C.

Influence of Porosity on Thermal Conductivity of Nickel: Conductivity of Nickel Oxide

VARIOUS AUTHORS: 'Thermal Conductivity.'
Jnl. Amer. Ceramic Soc., 1954, vol. 37, Feb. 1, Pt. II, pp. 67–110 (for papers referred to below see pp. 96–9; 99–102; 107–10).

This issue of *The Journal of the American Ceramic Society* contains a series of papers relating to thermal conductivity. Individual reports deal with factors affecting conductivity, methods of measurement, conductivity characteristics of materials which are of interest to the ceramic industry, and other aspects of the subject. The work recorded is part of an investigation which has been in progress at the Massachusetts Institute of Technology since 1949.

Among the contributions are two concerned with conductivity of porous materials:

A. L. LOEB: 'A Theory of Thermal Conductivity of Porous Materials.'

F. FRANCL and W. D. KINGERY: 'Experimental Investigation of Effect of Porosity on Thermal Conductivity.'

The second of these papers reports study of the effect of isometric, approximately spherical, pores and anisometric cylindrical pores, on the thermal conductivity of nickel, alumina, and graphite (materials of low, intermediate and high conductivity, respectively). It was found that the thermal conductivity of bodies having random porosity decreases proportionately to the volume pore fraction (or cross-sectional pore fraction). In bodies containing oriented anisometric pores conductivity decreases proportionately to the cross-sectional pore fraction. Orientation has a pronounced influence on conductivity. At temperatures above about 500°C. emissivity and pore size become important in determining the effect of porosity on thermal conductivity.

A further related paper by W. D. KINGERY, J. FRANCL *et al.*, is entitled 'Thermal Conductivity Data for Several Pure Oxide Materials Corrected to Zero Porosity.'

This report covers measurements of the thermal conductivities of several polycrystalline oxides at 100° to 1800°C. Data on nickel oxide (NiO) are included.

Effect of Hydrostatic Pressure on Curie Points of Nickel and Nickel Alloys

L. PATRICK: 'The Change of Ferromagnetic Curie Points with Hydrostatic Pressure.' *Physical Rev.*, 1954, vol. 93, Feb. 1, pp. 384–92.

The author records measurements of the effect of pressure on the Curie temperature of thirteen ferromagnetic materials, including nickel, iron, and cobalt, a 70–30 iron-nickel alloy used for 'compensation', Invar (36/64 per cent. nickel-iron alloy), Permalloy (nickel 68, iron 32, per cent.), Monel (high-nickel nickel-copper alloy), and Alumel (nickel 94 per cent., balance aluminium+small amounts of silicon and manganese). The pressures used varied up to 9,000 atmospheres. The results are discussed in relation to earlier literature, with which there is some disagreement.

See also—

R. SMOLUCHOWSKI: 'The Influence of Pressure on the Curie Temperature of Iron and Nickel.' *ibid.*, pp. 392–3.

A comparison is made between the measurements described in the previous paper and theoretical values based on a Brillouin function. For nickel the agreement between theory and experiment is within the limits of the validity of the theoretical assumptions made. For iron a quantitative comparison presents difficulties, although qualitatively the theory is in accord with the smallness of the observed effect.

Magnetic Characteristics of Thin Single-Crystal Nickel Films

L. E. COLLINS and O. S. HEAVENS: 'Magnetic Behaviour of Thin Single-Crystal Nickel Films.'
Philosophical Mag., 7th Ser., 1954, vol. 45, Mar., pp. 283–9.

The coercivity of monocrystalline films of nickel, grown epitaxially on the (100) face of rock-salt, was studied as a function of thickness over the range 200 Å to 1000 Å. Films grown in this way do not exhibit the granularity characteristic of films deposited on cold, inactive substrates; electron micrographs show continuity over distances of the order of several microns.

Spontaneous magnetization of the films is observed with the magnetization vector in the plane of the film. The high coercivity characteristic of a single domain structure is found and the maximum value agrees roughly with that calculated from the anisotropy constants. As would be expected, the behaviour of monocrystalline films differs markedly from that of the polycrystalline specimens.

Measurement of Magnetostriction in Nickel and Other Metals

A. W. COCHARDT: 'A Method of Measuring Magnetostriction.' *Jnl. Applied Physics*, 1954, vol. 25, Jan., pp. 91–5.

Torsion tests made on wires of various ferromagnetic materials, including nickel, iron, iron–nickel alloys and other alloys, show that the relationship between shear stress and shear strain is different for magnetized wires from that obtaining in unmagnetized wire. The difference is explained in terms of wall movement and rotation of ferromagnetic domains. Magnetostriction values are derived from it. It is pointed out that this method of measuring magnetostriction has several advantages: it is simpler to operate than most other

methods, its accuracy is 4×10^{-7}, and it can be carried out at elevated temperatures. Its main limitation is that saturation magnetostriction values are not obtainable for alloys which have a large crystal anisotropy energy.

Magnetostriction in Nickel

See abstract on p. 112.

Nickel in Depth-Recording Device

'Recording Echometer for Fishing Vessels. Spark Discharge on Dry Sensitized Paper.' *Engineering*, 1954, vol. 177, Apr. 23, p. 525.

The article describes a new recording echometer, developed by Marconi International Marine Communication Company, Ltd. Although intended primarily as an aid to navigation, by recording of the depth of water in which the vessel is travelling, the new 'Graphette' has been designed to give a clear indication of a shoal of fish, should such be present beneath the ship.

The apparatus, with the exception of the projector, is contained in a case suitable for bulkhead mounting: it is illustrated in this article. The projector, by which the ultrasonic waves employed for sounding are produced, is of the magnetostriction type, using nickel laminations. This part of the equipment is contained in a heavy casting located above a circular hole cut in the ship's shell plating near the keel. The waves are transmitted downwards in a vertical beam to the sea bed and are reflected upwards to a receiver, similar in principle to the projector and located in the hull of the vessel. They are thereby converted into electrical impulses which are applied to a recording apparatus registering on a horizontally-moving chart by means of a stylus travelling across the latter at constant speed. Method of calculation of depth, etc., from the recordings so made, is described in this article. An echometer of the 'Graphette' type has been successfully used on several trawlers and coastal vessels, including the research vessel 'Sarsia' of the Marine Biological Association at Plymouth.

Sub-Zero Electrical Properties of Nickel Films

A. VAN ITTERBEEK, L. DE GREVE, L. VAN GERVEN and K. SABBE: 'Measurements on the Electrical Resistivity of Thin Nickel Films at Very Low Temperatures.' *Physica*, 1954, vol. 20, Jan., pp. 1–6.

The paper deals with an investigation of the electrical and magnetic properties of very thin nickel films (produced by cathodic sputtering), at the temperatures of liquid helium and of liquid hydrogen. Electrical resistance was found to be a very sensitive function of temperature and measuring current, confirming measurements previously made on thin films of iron. The presence of an external magnetic field did not alter the current-dependence of electrical resistance. The existence of hysteresis was demonstrated by means of measurement of resistance. Coercive force of the thin films was found to be much greater than for bulk nickel.

Metal Film Catalysts

'Catalysis on Evaporated Metal Films.'

J. R. ANDERSON and C. KEMBALL: 'III. The Efficiency of Different Metals for the Reaction between Ethane and Deuterium.' *Proc. Royal Soc.*, Ser. A, 1954, vol. 223, May 6, pp. 361–77.

C. KEMBALL: 'IV. Exchange between Propane and Deuterium and Isobutane and Deuterium.' *ibid*, pp. 377–92.

In the work described in Part III the catalysts employed were films of tungsten, molybdenum, tantalum, zirconium, chromium, vanadium, nickel, platinum, palladium, rhodium, and ruthenium. In the experiments of Part IV films of tungsten, rhodium, and nickel were used.

Nickel-Alkaline Batteries in Marine Service

G. S. ATKINSON: 'Alkaline Batteries for Marine Purposes.' *Trans. Inst. Marine Engineers*, 1954, vol. 66, Feb., Abs. p. 28 (from *Shipbuilder and Marine Engine Builder*, 1953, vol. 60, Dec., pp. 689–91).

Alkaline batteries are in wide and increasing use for many marine purposes: they range in size from relatively small-capacity batteries for emergency lighting and ships' telephones to the large-capacity, high-voltage types used, for example, for emergency steering. Regulations on safety of life at sea, which have recently been introduced, call for additional safety measures, and these will be most satisfactorily met by utilizing the characteristics of alkaline batteries. For that reason there is a likelihood that the use of this type will expand still further in the near future.

In view of the fact that initially these batteries are relatively expensive, and that a main aim in using them is to secure long and trouble-free service, the author of this paper urges that particular attention should be given to selection of the best type for any specific service, and to suitable installation. It is pointed out that the tubular nickel-iron battery is best suited for applications calling for regular full charges and discharges, particularly where relatively high temperatures are involved: their principal use is in large private yachts, where regular cycling and persistent deep discharging are the normal conditions. The flat-plate nickel-cadmium battery is most generally used in commercial marine work, and it is important that the correct type should be selected for the specific conditions involved. One of the variations of the basic nickel-cadmium battery is a normal-resistance type, which should be used wherever the load consists mainly of moderate currents for considerable periods; the other is a low-resistance type, suitable for applications in which peak currents for relatively short periods are involved. The author also urges more careful maintenance as a means of ensuring that the optimum performance and life of batteries is secured, e.g., installation under conditions permitting a temperature as near as possible to 70°F. and never exceeding 115°F., adequate ventilation and drainage, easy accessibility to permit inspection and topping up.

Nickel in Marine Engineering

See abstract on p. 116.

Nickel-Magnesia Cermets

See abstract on p. 111.

Nickel Compounds in Rubber

'Nickel for Rubber.'
Corrosion Prevention and Control, 1954, vol. 1, May, p. 142.

'The behaviour of natural rubber, when subjected to the effect of atmospheric weathering, is of obvious importance in many practical applications. It has been known for some time that organic complexes of nickel and some other elements have a protective effect, and some recent work reported by the Institut Français de Caoutchouc has demonstrated that vulcanized latex shows high stability against sunlight if it contains 1·5 to 5 per cent. of nickel dibutyldithiocarbamate.'

Electrical Properties of Nickel Oxide

F. J. MORIN: 'Electrical Properties of NiO.'
Physical Rev., 1954, vol. 93, Mar. 1, pp. 1199–204.

Report of measurements of electrical conductivity, Seebeck effect*, and optical transmission, on sintered polycrystalline samples of NiO, prepared by thermal decomposition of chemically pure $Ni(NO_3)_2$. $NiCO_3$, or NiC_2O_4.

* The fact discovered, in 1821, that heating the point of contact of two dissimilar metals can produce an e.m.f.

ELECTRODEPOSITION AND OTHER COATING METHODS

Fourth International Conference on Electrodeposition and Metal Finishing: Discussion on Papers

'The 4th International Conference on Electrodeposition and Metal Finishing, London, 1954.'
Electroplating, 1954, vol. 7, May, pp. 175–91.

Abstracts of the papers, and a summary of the major points from discussions, are grouped in sections covering contributions relating to: (*a*) anodic processes, (*b*) fundamental aspects, (*c*) chromium and tin coatings, (*d*) nickel plating, (*e*) American electroplating practice, (*f*) organic finishing, (*g*) electrodeposition technique, (*h*) future research and prospects in the plating and finishing industry.

International Progress in Electrodeposition

I. S. HALLOWS (Editor): 'International Review of Metal Finishing.' Published, for '*Product Finishing*', by Sawell Publications, Ltd., London, 1954; 170 pp. Price 10/6.

In connexion with the Fourth International Conference on Electrodeposition*, a survey has been made of recent developments and present practice in the electroplating industry of twelve countries:—Great Britain, Belgium, Canada, Finland, France, Germany, Holland, India, New Zealand, Sweden, Switzerland, United States of America. The papers are well illustrated by photographs and diagrams showing plant and equipment in use in the respective countries.

* See abstracts of papers in *Nickel Bulletin*, 1954, vol. 27, No. 5, pp. 82-91.

Nickel-Chromium Plating of Automobile Parts

'Nickel–Chrome Plating. An Outstanding Plant at the Works of Vauxhall Motors, Ltd.'
Automobile Engineer, 1954, vol. 44, Apr., pp. 150–3.

This article describes the principal features of an automatic plating plant which is the largest in any motor-car works in England or in Europe. As part of the Luton Works of Messrs. Vauxhall Motors, Ltd., it comprises twenty-two pairs of process tanks, arranged in two parallel rows; the whole plant is 30 ft. wide and has a total length of 180 ft. Installation of this new equipment has made possible the full mechanization of dipping processes which were previously carried out partly by hand and partly by means of various forms of lifting tackle. In addition to flash plating, and nickel and chromium plating, the processes operated include cleaning by dip, spray-washing, and electrolytic cleaning.

The principal feature of the plant is the process conveyor system, of which a main interest is the method employed for raising suspended loads of components from one tank, transferring them, and loading them into the next processing tank. Details of the whole system are described, with illustrations.

The processing sequence is as follows:—

(1) The components are power-spray cleaned in an alkali solution, and this treatment is followed by electrolytic cleaning, using a solution of sodium cyanide and sodium carbonate. The preparatory stage is completed by water cleaning.
(2) Copper plating is begun by a sulphuric acid dip, followed by water spray and dip cleaning. This is followed by the copper cyanide plating, and by water swill and water swill-spray.
(3) The nickel-plating sequence starts with a sulphuric-acid dip, followed by water swilling and spraying. A special bright nickel-plating solution is used and a minimum deposit of 0·001 in. thickness is specified, produced by a treatment of 60 minutes. The tank used is 48 ft. long. Three cleaning operations, one by water swill and two by water swill and spray, complete the nickel-plating stage, and the work is immediately transferred to the
(4) Chromium-plating bath, where the solution consists mainly of chromic acid. The deposit specified is 0·00001 in. in thickness. The final step consists of four cleaning operations.

As illustrative of the close control exercized at all stages of the plating operations, it is noted that, in order to ensure the chemical cleanliness essential to successful operation of the bright-nickel plating solution, the system incorporates a small electroplating tank through which the continuously circulating solution passes before going to the mechanical filters, *en*

route for the processing tanks. This tank is arranged for low-current-density plating, to remove contaminants from the solution. The mechanical filters deal with 6,000 gallons of nickel solution per hour.

In addition to the control methods used in operation, every plated component undergoes visual inspection before leaving the plant, and frequent tests are made to ensure that the specified minimum thicknesses of copper, nickel and chromium are being consistently secured.

Plating by Thermal Decomposition of Volatile Metal Compounds

'Commercial Gas Plating Process.' *Electroplating*, 1954, vol. 7, Jan., pp. 16–18 (reprinted from *Steel*, 1953, vol. 133, Oct. 19, pp. 120, 124; see abstract in *Nickel Bulletin*, 1953, vol. 26, No. 12, p. 206).

Production of Nickel-plated Piping for Atomic-Energy Plant

E. ALTHOLZ: 'Atomic Energy Production Requires Nickel-plated Pipe.' *Machinery* (*N.Y.*), 1954, vol. 60, Mar., pp. 167–72.

An important recent development in the plating field is the treatment of long lengths of piping, of 20–54 in. diameter, for use in atomic-energy plants, where a nickel coating is used to ensure freedom from contamination in the products handled. This article describes methods employed in the plant of Alco Products Division of the American Locomotive Company, in fabrication of the pipe (by welding of formed mild-steel sheet), and nickel plating.

The plating process, although involving no fundamentally new process developments, presented the considerable engineering problem of handling larger and heavier masses of piping than had previously been treated on a production basis. The pipe is supported in a vertical position during both the preparatory and the plating operations, thus necessitating large head room in the plant: the floor area required is also large, to accommodate the battery of tanks, which are 22 ft. deep and have diameters up to 9 ft. The handling of the piping is illustrated in this article.

Nine operations are used in the nickel-plating cycle: alkaline cleaning; cold-water rinsing; sulphuric-acid cleaning; cold-water rinsing; muriatic-acid cleaning; cold-water rinsing; nickel plating; final rinsing, first with cold and then with hot water. The importance of the preliminary operations, in ensuring 'surgically clean' piping for plating, is emphasized as a *sine-quâ-non* of success. In the plating bath special fixtures hold nickel anodes wrapped in cloth filters, suspended within the pipe, and the work itself forms the cathode. Anodes which have been consumed beyond the point of suitability for use in internal plating are employed for plating the outside of the piping. (Plating of the exterior, although not functionally essential, prolongs the purity of the solution.) During treatment the bath is continuously agitated, to ensure production of a uniform deposit.

The specifications laid down by the U.S. Atomic Energy Commission call for a high standard of adherence, and minimum porosity in the coating. Adherence is tested by a bend test on a small piece of the steel from which the pipe has been made and which has accompanied it through the whole preparatory and plating cycle. The specimen is bent through 180 degrees round a 2-in. mandrel, straightened, and then bent through 40 degrees in the opposite direction. The requirement is that under this test no flaking, chipping, or peeling must occur. To ensure against porosity, the piping is subjected to a severe mass spectrophotometer test.

Plating of Lead- and Tin-base Alloys

J. HAAS: 'Plating on Lead Alloys, Pewter and Britannia Metal.' *Metal Finishing*, 1954, vol. 52, Apr., pp. 56–61.

This article is designed to bring together the scattered information available on plating of lead- and some tin-base alloys, with particular reference to some of the problems which have arisen since the introduction of bright-nickel and chromium plating. The procedure generally used in earlier years is briefly reviewed, and this summary is followed by a discussion of the factors which must be understood when processing lead- and tin-base materials, and by detailed recommendations for polishing, cleaning, and plating of such alloys. Some of the main points are noted below:—

The standard method of polishing lead alloys is by sand bobbing, using a correct grade of greaseless compound: subsequent buffing is preferably done with a sheepskin or chamois buff, applying white compound to the wheel at a spindle speed not exceeding 1800 r.p.m. Buffing compounds should be removed by soaking in an emulsion cleaner, preferably with agitation, followed by warm water rinsing or spraying, and treatment in a trichloroethylene degreaser.

Cleaning media containing carbonates, phosphates, and silicates should be avoided, and after alkaline cleaning acid dipping must be used as neutralizer. A suitable alkali cleaner is best used cathodically, in low concentration, and at 170°–180°F. (76°–83°C.). Current density should not exceed 20 amp./sq. ft., and the cleaning time should be short, 10 secs. to 1 min. After alkaline treatment the work should be rinsed in warm water. With regard to acid dips, the author draws attention to the undesirability of using sulphuric- or hydrochloric-acid solutions. Fluoboric acid is generally employed (concentration 10 per cent. by volume): treatment is for 5–15 seconds at room temperature.

Nickel can be electrodeposited direct on lead alloys, and the author strongly recommends the fluoborate bath as being best suited to deposit a ductile coating. This type of bath has been used to some extent in plating novelty items of lead-base alloys, but has not, to the writer's knowledge, yet been used in the hollow-ware industry. The advantages of fluoborate solutions include high conductivity, high efficiency, good mechanical properties and low stress in the deposited coatings, high buffering capacity, ease of control, stability, and a wide range of operating conditions. Such solutions are highly corrosive, but plating equipment which will withstand attack is commercially

available. A good general-purpose nickel fluoborate bath for plating on lead alloys has the following composition (oz./gal.): nickel fluoborate 40, boric acid 4. The pH is 2·7–3·5, and the bath is operated at a temperature of 110°–130°F. (43°–60°C.), with voltage 3·5–4·5.

Copper can also be directly plated from a cyanide solution onto lead-base materials: a copper undercoat may be suitably employed as a base for bright-nickel coatings, and is also useful in equalizing the strain involved in nickel plating, since the coefficient of expansion of copper is intermediate between that of lead and that of nickel. In the interests of avoiding blistering of the plated parts, it is important to ensure an adequate undercoat of copper, i.e., not less than 0·0003 in.

Nickel-plated antimonial-lead alloys must be chromium plated with care: the operation should not exceed three minutes' duration, at 100 amp./sq. ft., and every possible means should be taken, by correct racking and by close control of current density, to prevent burning of the deposit.

The final section of this practical article contains a series of flow charts giving step-by-step directions for silver- and for chromium-plating of parts made from lead alloys, pewter, or Britannia metal.

Nickel-Phosphorus Coatings: the 'Niphos' Process

G. J. HARVEY: 'New Low-Cost Coating Gives Mild Steel Good Corrosion-Resistance.' *Iron Age*, 1954, vol. 173, Apr. 15, pp. 125–7.

The author describes the main features of a coating process developed by New York Testing Laboratories, Inc., which is claimed to be simple in application and highly effective. A mixture of nickel oxide (preferably green oxide), dibasic ammonium phosphate, and water is made, to paste, paint, or spray consistency. The mixture is applied by brushing, dipping, or spraying, to the surface to be treated, and the coated part is heated at 1600°–2000°F. (870°–1105°C.). The ratio of nickel oxide to ammonium phosphate may vary from 2:1 to 20:1, depending on the firing temperature which is to be used: the higher the proportion of phosphorus carrier to nickel oxide in the mixture the lower is the temperature required for reduction and for fusing and bonding. The firing time required is only that sufficient to secure a skin heat of the required temperature: it is therefore possible to apply heavy coatings relatively quickly and cheaply.

Microscopic examination indicates that the coatings so formed are bonded strongly to the base and alloyed with it: a ternary iron-nickel-phosphorus alloy forms at the interface of base metal and coating, and it is claimed that this imparts to the coating the ductile properties of the basis metal, although the surface of the coating itself is hard.

The nickel-phosphorus coating offers good resistance to attack by salt spray, to atmospheric corrosion, and to dilute nitric-acid solutions. Porosity, which is an important factor in this connexion, can be reduced to a minimum by correct balancing of the nickel-to-phosphorus ratio: porosity tends to rise with increase in the ratio of phosphorus carrier to nickel oxide in the mixture.

The reactions occurring in processing are described as follows:—

In the first reaction diammonium phosphate reacts with the nickelous oxide and the hydrogen of the reducing gas, to produce an alloy of nickel and phosphorus which contains about 10 per cent. of phosphorus, the eutectic alloy of this system. Other products resulting from this reaction are ammonia, water vapour, and phosphine. In the second reaction the phosphine reacts with some of the nickelous oxide, to produce a mixture of nickel and a nickel-phosphorus alloy. This mixture forms a protective coating in which the percentage of phosphorus is usually less than 3 per cent.

Reference is made to the use of this method for, *inter alia*, the treatment of the interior surfaces of pipes. The initial mixture of nickel oxide, ammonium phosphate and water is run through the pipe while the latter is rotated. The coating is dried, and the work is fired by passing it through rotary burners or an induction coil. The reducing atmosphere can be passed through the pipe and burned at the other end while firing takes place.

Estimation of Boric Acid in Nickel-Plating Solutions

M. R. VERNON and K. C. AGRAWAL: 'Analysis of Electroplating Solutions. I. Estimation of Boric Acid in the Presence of Nickel Salts.' *Electroplating*, 1954, vol. 7, May, pp. 171–2.

Heavy-metal ions (e.g., zinc, lead, iron, aluminium, nickel), fluorides, and ammonium salts are known to interfere in the direct determination of boric acid. The authors of this note briefly summarize the salient features of the various methods which have been proposed to overcome the difficulty, concluding that all the procedures suggested suffer from the drawback of either being too lengthy, or requiring treatment with an expensive or poisonous reagent for complexing. They then give full details of a method for estimation of boric acid in the presence of nickel salts, using potassium oxalate as the complexing agent. Results of tests confirming the accuracy obtainable by this procedure are reported.

Determination of the Thickness of Bright-Nickel Coatings by the Jet Test

J. EDWARDS: 'The B.N.F. Jet Test on Organic Bright Nickel Deposits.' *Bull. Inst. Metal Finishing*, 1954, vol. 4, Spring, pp. 33–46; *Trans. Inst. Metal Finishing*, 1954, vol. 30.

The B.N.F. Jet Test, developed many years ago by CLARKE and others, is a widely used method of determining the thickness of electrodeposited coatings. On dull-nickel deposits the test has proved capable of giving consistent and reliable results, but the rate of penetration, by the jet-test reagent, of bright nickel coatings deposited from organic solutions is known to be more rapid than that occurring on dull-nickel

coatings. Following considerable research and comparison of results on dull and bright coatings, the conclusion was arrived at that when jet-testing bright deposits the apparent thickness should be multiplied by 1·5 to give the true thickness. This correction factor was originally determined from deposits made from baths containing sulphonic acids, but has since been applied to bright coatings deposited from solutions containing a variety of proprietary addition agents. Cases of suspected inaccuracy in thickness determination on bright deposits have, however, been reported, and a further investigation has therefore been carried out in the laboratories of the British Non-Ferrous Metals Research Association.

On a number of specimens prepared with accurately uniform deposits, comparison of jet-test results with the mean of several microscopic measurements of thickness showed that rate of penetration varied to a significant extent with the thickness of the deposit. Later work was therefore concentrated on deposits of various thicknesses deposited under standard conditions. The influence of plating conditions was studied:—current density, temperature, and concentration of brightener. The influence of buffing the coating was also investigated. Most of the work was done with deposits made from Efco-Udylite baths, but some tests were also made on coatings deposited from the Super Gleamax type of solution. In this paper a detailed report is made of both series of tests.

The results confirm the unsuitability of a standard ×1·5 correction factor for the thickness of bright, as compared with dull, deposits, when using the jet-test method. Since rate of penetration varies with thickness, much more reliable results are obtainable by using a calibration curve to convert apparent to true thickness. The work on the Efco-Udylite deposits showed that from a given bath of this type the calibration of the test is not greatly affected by reasonable variations in temperature, current density or concentration of brightener, or by buffing the deposit after plating. Differences found between the calibration curves for the Efco-Udyiite and the Super-Gleamax deposits demonstrate the need for development of a curve for each type of organic nickel deposit, but this problem is complicated by the fact that in the case of Super Gleamax deposits variations may be found between coatings deposited from baths of nominally identical type. It is therefore considered probable that, even with appropriate calibration curves, the accuracy of the jet test as applied to organic bright-nickel deposits is likely to be lower than that obtainable on dull-nickel coatings.

In view of these findings, it is suggested that unless the calibration curve can be completely checked from time to time on deposits from a given bath, the jet test should be used primarily as a 'limit' test, not as a means of measuring actual thickness. According to this procedure a sample would be bright-nickel plated to the thickness required, and its thickness would be checked microscopically, or by some other method known to give accurate results. The apparent thickness would be determined by the jet test, and an article attaining this apparent jet-test thickness would be regarded as satisfactory, whereas one which appeared to be thinner would be further examined, for example, by taking a microsection, and, if it failed to meet the thickness specification, the batch represented would be rejected.

(The work described in this paper was made available to members of the British Non-Ferrous Metals Research Association in confidential reports issued in May, 1952 and October, 1953.)

German Specifications for Electrodeposited Coatings

G. SCHIKORR: 'The Present Position of Standardization in Germany, as a Basis for the Investigation of Electrodeposited Coatings.' *Metalloberfläche*, 1954, vol. 6, Jan., pp. B 57–B 60.

German standard specifications in the electroplating field fall into three categories: descriptive, quality, and testing schedules. This article discusses the testing group, dealing with methods laid down for determination of thickness of coating, porosity, and corrosion-resistance, and for the assessment of physical properties of coatings. A list is given of current D.I.N. specifications relevant to testing of all types of electrodeposited coatings.

Chemical Methods for Determination of Thickness of Electrodeposited Nickel Coatings

G. SCHIKORR: 'Determination of the Thickness of Thin Nickel Coatings on Iron by Dissolving Away the Coating.' *Metalloberfläche*, 1954, vol. 6, Apr., pp. B 49–B 51.

The author opens with a condensed discussion of some of the difficulties inherent in determination of thickness of electrodeposited coatings, and directs attention to the paucity of information available in the literature on the extent to which the basis materials are attacked in the course of dissolving away coatings by various chemical procedures used in thickness testing. An account is then given of tests made by the writer with various methods of chemical removal of nickel coatings electrodeposited from a Watts-type bath.

Details are given, in each series, of

weight of ferrous base before plating
„ „ specimen after plating
„ „ ferrous base after removal of plating
„ „ nickel deposited, as calculated by weight of test piece in the respective conditions
„ „ nickel found by chemical removal.

Appropriate information on sizes of test pieces is given, to permit calculation of thickness of coatings.

The conclusions drawn with regard to the suitability of various chemical removal treatments are summarized below:—

(1) *Anodic solution in 70 per cent. sulphuric acid* gave results showing too wide a scatter to be suitable for accurate assessment of thickness of the thinner grades of nickel coating covered by D.I.N. specification 50 960. (Since the indications were that simple solution methods were more promising, no attempt was made by the author to study modifications of this procedure which might make possible a closer degree of accuracy.)

(2) *Removal by solution in fuming nitric acid.* The warning is given that at the end of the solution period

it is necessary to rinse the de-plated iron or steel in chromic-acid solution prior to water rinsing, in order to preserve the passivity of the ferrous material during the latter operation. This procedure was found to give results closely consistent with the control values.

(3) *Removal by solution in a 50–50 solution of fuming and concentrated nitric acids.* Found to be less consistent than results given by dissolving in straight fuming nitric acid solution: not recommended.

(4) Since iron or steel is, unless passified, subject to attack by fuming nitric acid, the author attempted to develop a less drastic solution for removal of the nickel coatings. *A mixture containing 100 g. sodium cyanide, 20 g. ammonium persulphate, in 880 g. distilled water* was found to be especially suitable from the point of view of accuracy, but the procedure has the disadvantage that a longer time is required for removal of the coating and that while the solution is in use a brownish scum is formed, to the extent, in removing nickel coatings of considerable thickness, of necessitating renewal of the solution during a single test. The mixed solution cannot be used twice, which accentuates its disadvantages vis-à-vis the simple fuming nitric-acid bath.

In measuring the thickness of nickel coatings which have been deposited on an undercoat of copper the danger of attack of the basis metal is less than with nickel deposited direct on a ferrous base. To determine the extent to which the solutions referred to above would attack copper, tests were made on nickel-plated copper sheet. With the anodic process attack on the copper was so small as to be practically negligible, and the method may therefore be considered suitable for use on nickel coatings deposited on copper, whereas parallel tests on nickel coatings deposited direct on steel revealed heavy attack on the ferrous base, confirming the unsuitability of this procedure for application to nickel coatings deposited without copper underlay. Fuming nitric acid, and the mixed cyanide-persulphate solution, attacked the copper so vigorously as to render them entirely unsuitable for use on nickel coatings electrodeposited over copper. In such cases anodic treatment in sulphuric-acid solution may be used to remove the nickel, followed by removal of the copper separately by fuming nitric acid or the mixed solution, weighing the test piece (*a*) before removal of the nickel, (*b*) after removal of the nickel and before removal of the copper, and (*c*) after removal of the copper.

Porosity Testing of Coatings on Zinc-base Die Castings

H. K. LULWAK: 'A Porosity Test for Electrodeposits on Zinc-base Die Castings.' *Metal Finishing*, 1954, vol. 52, Apr., pp. 76–8.

A new method for porosity testing of electrodeposited coatings on zinc-base die castings, developed at the Defence Research Laboratories, Victoria, Australia, employs a test solution containing ammonium chloride and potassium ferrocyanide. The ammonium chloride corrodes the zinc at the bottom of the pores and keeps the zinc in solution: the ferrocyanide forms a white insoluble compound with the dissolved zinc. Recommended procedure is given below:

'*Solutions and Equipment*

(*a*) Dissolve 80 g. of ammonium chloride and 80 g. of potassium ferrocyanide, $K_4Fe(CN)_6.3H_2O$, in water at room temperature, and dilute to 1 litre. Filter solution that has become turbid before use.

(*b*) Cut pulp paper (impregnated with carbon black) as used for wrapping light-sensitive materials, or smooth white paper, to size required by the shape of the specimens.

(*c*) Dissolve 10 g. of shellac in 1 litre of alcohol. After standing, decant the clear liquid from the sediment of shellac wax.

(*d*) Dissolve 10 g. of ferric chloride, $FeCl_3.6H_2O$, in water and dilute to 1 litre.

(*e*) Dissolve 200 g. copper sulphate in water, add 30 ml. sulphuric acid and dilute to 1 litre. Alternatively, acid copper-plating solution can be used.

'*Degreasing*

Degrease the specimens in an organic solvent such as benzol or carbon tetrachloride and then clean with magnesium oxide–water paste and rinse.

'*Testing of Irregularly Shaped Articles*

Wash the degreased specimens with alcohol to remove water, then dip them into shellac solution and dry in hot air (avoid flame). Submerge the specimens completely in the test solution for about 20 minutes, then remove them carefully, rinse, and dry. If a permanent record is required, the specimens may be photographed. Clean specimens which have passed the test thoroughly with alcohol before using them commercially.

'*Testing of Flat, Cylindrical or Conical Articles*

Soak the black (or white) paper in the test solution, and shake free from excess liquid. Place the moist papers on the degreased specimens and press the backs of the papers to remove air bubbles. Remove the papers from the specimens after 10 minutes.

(*a*) Dry the black papers without rinsing.

(*b*) Rinse the white papers thoroughly for about 20 minutes in a stream of running water, until substantially all test solution absorbed by the paper has been washed out. Immerse the papers in either the ferric-chloride or the copper-sulphate solution and rinse and dry the papers after the coloured spots have appeared.

The test papers are permanent records.'

An account is given of some experiments carried out, in the course of developing the test, on zinc-base alloys coated with porous deposits of copper and nickel. These indicate that attack on the plating metals is negligible.

NON-FERROUS ALLOYS

Nickel-Copper Compensation Alloy

HENRY WIGGIN AND CO., LTD.: 'JAE Metal.' *Publn. 725*, Apr., 1954; 4 pp.

JAE Metal, an alloy containing nickel 70, copper 30, per cent., is characterized by a high temperature

coefficient of magnetic permeability: in the annealed condition it has a Curie point of about 70°–75°C. It is used for compensating shunts on magnetic speedometers, electricity meters, and other instruments in which it is necessary to compensate for variations in the electrical and magnetic characteristics of parts of the instrument, resulting from changes in the ambient temperature.

This publication contains tables showing the physical properties of the alloy (including thermal coefficient of linear expansion over various temperature ranges), also typical mechanical properties and hardness. Magnetic properties are illustrated by (1) B–H curves at various temperatures and (2) curves showing relation between magnetic induction and temperature, and between magnetic permeability and temperature, at various field strengths.

Copper-Nickel Alloy Thermocouple Wire

HENRY WIGGIN AND CO., LTD.: 'Ferry Thermocouple Wire and Compensating Leads.' *Publn. 724*, Apr., 1954; 4 pp.

Choice of materials for thermocouple elements depends on (*a*) the temperature which is to be measured, (*b*) the stability of the thermo-electric properties of the material, and (*c*) the reproducibility of these properties from batch to batch. Ferry, a copper-nickel alloy of carefully controlled composition, when used *vs.* high-conductivity copper, is a satisfactory combination for measurement of temperatures up to 350°C. By using pure iron in place of copper the usefulness of the thermocouple is extended to at least 800°C. Tables in this publication give figures for calibration of standard thermocouple Ferry (T. C. Ferry) *vs.* (1) copper and (2) pure platinum. The Ferry wire is supplied in all gauges.

Monel Bellows

See abstract on p. 120.

Young's Modulus of Nickel-Aluminium and Nickel-Copper-Zinc Alloys

T. FUKUROI and Y. SHIBUYA: 'The Measurement of the Young's Modulus of Metals and Alloys by an Interferometric Method. III. The Influence of Heat-Treatment on the Young's Moduli of Iron-Aluminium Alloys and the Young's Moduli of Nickel-Aluminium Alloys, Aluminium-Copper Alloys and German Silver in the Annealed State.'
Science Repts. Research Inst., Tôhoku Univ., Ser. A, 1953, vol. 5, No. 5, pp. 405–12.

Using the method described earlier (*ibid.*, 1950, vol. 2, pp. 748 and 829), and following an investigation of the Young's moduli of nickel-copper and nickel-manganese alloys, the authors now describe measurements on iron-aluminium alloys (aluminium up to 14·75 per cent.), nickel-aluminium alloys (aluminium up to 5·17 per cent.), aluminium-copper alloys (copper up to 27·47 per cent.), and nickel-copper-zinc alloys containing 14·55 to 24·49 per cent. nickel with zinc falling from 32·54 to 24·84 per cent.

Nickel Alloys in Marine Engineering

See abstract on p. 116.

Nickel-containing Materials in P. & O. Liner 'Arcadia'

See abstract on p. 119.

Welding of 90-10 Copper-Nickel Alloys

G. R. PEASE and T. E. KIHLGREN: 'Welding of 90–10 Copper-Nickel Alloys.' *Welding Jnl.*, 1954, vol. 33, Apr., pp. 329–38.

Although considerable research has already been carried out on the corrosion-resisting properties of iron-modified 90–10 copper-nickel alloys, and data on structural characteristics have also been published, relatively little information has until now been available with regard to the capacity of the alloy for welding by generally used methods.

The present paper reports investigations carried out by The International Nickel Company's Research Laboratory at Bayonne, New Jersey, in which the applicability of the following welding procedures was systematically studied:—

Flux-shielded metal-arc (coated electrodes).
Inert-gas-shielded tungsten arc.
Inert-gas-shielded metal-arc.
Oxy-acetylene.
Submerged arc.

In addition, some work was done to determine response to silver brazing.

The plate and sheet material used was rolled from a single heat of commercial low-phosphorus 90–10 alloy. It was supplied as 1-, $\frac{3}{8}$-, $\frac{1}{4}$- and $\frac{1}{8}$-in. hot-rolled plate and 0·062 × 3 in. cold-rolled and annealed strip.

The results of the whole series of tests lead to the conclusion that the welding of the iron-bearing cupro-nickel, by any one of the methods mentioned, offers no unusual problems. The choice of welding method in specific applications must obviously be governed, as in welding other materials, by several factors, such as cost, availability of equipment, and thickness of material involved. Some of the points emphasized in connexion with the use of individual methods of welding are briefly noted below:—

Metal-arc Welding with Coated Electrodes: It was already known that strong, ductile welds can be made in the 90–10 alloy by using 70–30 cupro-nickel electrodes. In the present investigation, which was designed to develop a 90–10 electrode of equal suitability, it was found that small amounts of silicon must be added to the core wire, to ensure freedom from porosity, but that the silicon addition must be controlled in relation to the lead content. If the 0·05 per cent. maximum lead content now required in the base-metal specifications for this type of alloy is to be applied to the filler material, not more than about 0·15 per cent. of silicon can safely be added to 90–10 weld metal. If lead can be held to 0·02 per cent. the permissible silicon content can be doubled, and, with lead at 0·01 per cent., silicon up to about 0·40 per cent. may be incorporated. These considerations apply mainly to welds made under heavy restraint, as in

rigid structures or heavy-gauge material. In light-gauge welding wider latitude can probably be tolerated.

Inert-gas-shielded Tungsten Arc Welding: The 90–10 alloy can be readily inert-gas welded with a tungsten electrode, either with or without a filler wire, but weld quality is less sensitive to variations in welding conditions when the application is such that a suitable filler metal can be added. In general, weld quality was found to deteriorate as the arc length and speed of welding increased. For a given arc length and speed of welding, weld quality was consistently better with helium than with argon. The following specification is suggested for the filler-wire composition for inert-gas-shielded arc welding:

	Composition %
Nickel	9·00–11·00
Iron	1·00– 1·75
Manganese ..	0·25– 0·75
Silicon	0·20– 0·40
Titanium	0·50– 0·20
Magnesium ..	0·05 max.
Lead	0·01 max.
Sulphur	0·01 max.
Other metals ..	0·50 max.

It is noted that for optimum performance the combination of silicon and titanium is essential.

Inert-gas-shielded Consumable-Electrode Process: The filler-metal composition shown above proved entirely suitable also in this case. Argon is to be preferred to helium.

Oxy-acetylene Welding: The response of the alloy to oxy-acetylene welding was poorer than to any other of the methods studied. Moderately satisfactory welds were obtained in 0·062-in. sheet, but as the joint thickness increased weld quality deteriorated. At least some of the difficulty is believed to be due to the high heat conductivity of the alloy, which makes it difficult to maintain a molten pool of the correct size without local overheating. Silicon was effective in reducing weld porosity; titanium proved unsuitable. An all-halide flux provides better protection and better control of the pool than a borax-type flux: a slightly reducing flame is to be preferred to either a strongly reducing or an oxidizing flame.

Submerged-Arc Welding: The limited amount of work done on this process was sufficient to demonstrate that ductile, pore-free welds can be obtained by using a silicon-containing 90–10 copper-nickel core-wire composition or the silicon-titanium modification given in the table above.

Particular attention is drawn to the fact that at no stage in the investigation, with any of the welding methods investigated, was any indication found of liability to embrittlement arising from precipitation of the iron in the parent or the weld metal.

Silver Brazing: The response of iron-bearing 90–10 cupro-nickel appears to be closely similar to that of other binary copper-nickel alloys. Best results were obtained when clearances did not exceed 0·005 in., and in general phosphorus-free grades of silver-brazing alloy are to be preferred. A conventional, low-melting-point fluoride-borate flux provides adequate protection for torch brazing, and a dry hydrogen atmosphere proved suitable for furnace brazing, using phosphorus-free grades of alloy. Like other alloys in the copper–nickel system, the 90–10 alloy was found to be susceptible to intergranular embrittlement if exposed, while stressed, to molten brazing alloy. To avoid this attack the usual recommendation is made, viz., that only material which has been stress-relief annealed should be used, and that jigging and assembly should be arranged in such a way that any areas in contact with molten solder are free of applied stress.

Ordering Reactions in Nickel-Chromium Alloys: Electrical-Resistivity Studies

R. NORDHEIM and N. J. GRANT: 'Resistivity Anomalies in the Nickel–Chromium System as Evidence of Ordering Reactions.' *Jnl. Inst. Metals*, 1953–54, vol. 82, May, pp. 440–4; Advance Copy 1536.

The resistivity anomaly in the nickel–chromium system (tentatively attributed by some earlier investigators to an ordering reaction) has recently been studied in detail by TAYLOR and HINTON: *ibid.*, 1952–53, vol. 81, pp. 169–80; *Nickel Bulletin*, 1953, vol. 26, No. 1, p. 10. The characteristic feature of the anomaly is that during annealing after non-equilibrium cooling resistivity increases towards an equilibrium value. This increase is sufficiently marked to cause a minimum on the resistivity/temperature curve. The suggestion that the increasing resistivity below 700°–800°C. is caused by ordering is supported by the fact that the effect is strongest for the alloy having a composition corresponding to Ni_3Cr and that the phenomenon is associated with a lattice contraction and an evolution of heat. Although ordering normally causes decrease in resistivity, TAYLOR and HINTON showed that in the nickel–chromium system the change in the Brillouin zones during ordering may result in increased resistivity. None of the investigators who have studied the subject have been able to detect positively any superstructure in the X-ray pattern of annealed nickel–chromium alloys, but such lines have been definitely observed in the pattern of an alloy in which one-fifth of the chromium atoms was replaced by aluminium, a modification which would tend to increase the intensity of the superstructure diffractions. From specific-heat data the critical ordering temperature was determined as 544°C.

The present paper reports results of study of the resistivity phenomenon in binary nickel–chromium alloys containing (at. per cent.) 10·9, 22·2, 25·0, 32·0 and 35·7 chromium.

The authors' results lead them to confirm that the resistivity effects are associated with ordering. They point out, however, that the facts that (*a*) no superstructure lines have been detected in the X-ray pattern of annealed nickel–chromium alloys, and (*b*) no discontinuity in the equilibrium-resistivity curve for alloys containing 25 per cent. chromium has been observed, make long-range order improbable. The gradual increase in the magnitude of the effect observed as being associated with falling temperature, however, gives strong support to the theory of short-range order. During long-time annealing at temperatures below 500°C. the resistivity of alloys

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containing more than 30 per cent. of chromium was found to decrease to a marked extent, and this change was associated with a large increase in hardness and considerable lattice contraction. No microstructural alteration could, however, be detected. Although no superstructure lines could be observed in the X-ray pattern of these alloys, the fall in resistivity and the lattice contraction are indicative of long-range ordering, and the increased hardness, characteristic of the CuAu type of ordering, supports this assumption.

Effect of Radiation on Order-Disorder Changes in Nickel-Manganese Alloys

L. R. ARONIN: 'Radiation Damage Effects on Order-Disorder in Nickel-Manganese Alloys.'
Jnl. Applied Physics, 1954, vol. 25, Mar., pp. 344–9.

Effects of fast neutron irradiation, in a nuclear reactor, on order-disorder in a series of nickel-manganese alloys containing 16·5–31·9 at. per cent. manganese were studied by means of resistivity and magnetic measurements. Attainment of an 'irradiated state', differing from either cold-work or thermal disordering, is suggested by comparison of the results of exposure of specimens of Ni_3Mn: (*a*) initially disordered by cold work, and (*b*) initially disordered by thermal treatment. In a region from 16·5 to approximately 22 per cent. manganese, thermally-disordered alloys are markedly affected by irradiation, and these effects appeared to be superposed on disordering produced by irradiation of initially ordered alloys.

Copper-Nickel-Palladium Alloys

V. A. NEMILOV and T. A. STRUNINA: 'Investigation of the System Copper-Nickel-Palladium.
Izvest Sektora Platiny i Drug. Blagorod. Metal., Inst. Obschei i Neorg. Khim., Akad. Nauk. S.S.S.R., 1951, vol. 26, pp. 25–33; *Chemical Abstracts*, 1954, vol. 48, Mar. 10, p. 2548.

'A study of 46 different alloys of the system copper-nickel-palladium resulted in the establishment of liquidus lines for constant percentages of palladium. Graphs show the effect of increasing nickel content (with constant palladium), on hardness, electrical resistance, and temperature coefficient of electrical resistance. Photomicrographs of several alloys are included, and a constitutional diagram of the ternary system is given.'

Nickel-Magnesia Cermets

E. T. MONTGOMERY and P. E. REMPES: 'Exploratory Study of Nickel-Magnesia Cermets.' *Wright Air Development Center Tech. Rept.* 53–164, Apr., 1953; 6 pp.

The report covers work done at Ohio State University, under contract for the Air Research and Development Command, U.S. Air Force.

In view of successful development of nickel-magnesia cermet coatings for parts exposed to high temperature and corrosive gases, an exploratory study has been made of the properties of solid cermets of this type. The initial work, which was done on bodies comprising fused magnesia bonded with 38·8 or 71·6 weight per cent. of nickel, was concerned with determination of the best sintering treatment, as judged by modulus-of-rupture properties obtained at room temperature. The 38·8 per cent. nickel alloy showed strength values too low to warrant further tests of this composition, but the 71·6 per cent. nickel cermet, sintered under optimum conditions, was subjected to transverse-strength tests at 75°, 1800°, 2000° and 2200°F. (23·8°, 981°, 1093° and 1204°C.). Firing-shrinkage, apparent porosity, high-temperature oxidation-resistance and resistance to thermal shock were also investigated for this material.

On the basis of the limited number of tests made, it is considered that nickel and magnesia solid-body cermets are less promising than other oxide-base cermets.

Shell-Moulding of Nickel Alloys

See abstract on p. 118.

NICKEL-IRON ALLOYS

Transformations in Nickel-Iron and Nickel-Iron-Carbon Alloys

J. S. BOWLES and J. K. MACKENZIE: 'The Crystallography of Martensite Transformations III. Face-Centred Cubic to Body-Centred Tetragonal Transformations.' *Acta Metallurgica*, 1954, vol. 2, Mar., pp. 224–34.

The geometrical theory of martensite transformations developed in Parts I and II of this series of reports (*ibid.*, 1954, vol. 2, p. 129) is applied to transformations from face-centred cubic to body-centred tetragonal structure in iron-carbon, iron-nickel and iron-nickel-carbon alloys. The theoretical predictions of habit planes, orientation relationships, and directions of the homogeneous strain are found to be in satisfactory agreement with all available experimental data. The hypothesis that the inhomogeneous shear is part of the twinning shear in the final structure has thus been substantiated for the transformations considered.

Deformation of Austenite in Nickel-Iron Alloy during Martensitic Transformation

B. EDMONDSON and T. KO: 'Spontaneous Deformation of Austenite during Martensitic Transformations.' *Acta Metallurgica*, 1954, vol. 2, Mar., pp. 235–41.

Metallographic examination has shown that plastic deformation takes place in austenite during the martensitic transformations occurring in a 34 per cent. nickel nickel-iron alloy during both heating and cooling. Permanent distortion remains after all the martensite has reverted to austenite, and this distortion is shown to have an important effect on subsequent formation of martensite. Slip lines in austenite were observed also in steels containing:—(*a*) nickel 18, carbon 1, per cent., and (*b*) nickel 5, carbon 1·5, per cent. The effects of spontaneous deformation on the kinetics of martensitic transformation are discussed.

Mechanical Properties of High-Purity Iron-Nickel Alloys

W. P. REES, B. E. HOPKINS and H. R. TIPLER: 'Tensile and Impact Properties of Fe-Si, Fe-Ni, Fe-Cr and Fe-Mo Alloys of High Purity.' *Jnl. Iron and Steel Inst.*, 1954, vol. 177, May, pp. 93-110.

As a part of a general programme covering investigation of the influence of alloying elements on the mechanical properties of ferrite, a study is being made of the effect of a number of elements on the tensile and notched-bar impact properties of high-purity iron, over a range of temperatures spanning the tough-to-brittle transition. Results relating to the influence of manganese, carbon, carbon+manganese, and oxygen have already been published in this Journal. The present paper covers high-purity iron alloys containing silicon, nickel, chromium, and molybdenum, used singly, in amounts up to 5 per cent.

Silicon. Low brittle-fracture strengths and high transition temperatures in iron-silicon alloys are attributed largely to intergranular brittleness: a large rise in transition temperature in tension and impact caused by increase in silicon content is believed to be due mainly to the large rise in yield stress, since there is little change in the brittle strength. Refining the grain size of a 1 per cent. silicon alloy eliminated failure at the grain boundaries and resulted in a considerable fall in transition temperature compared with that of iron.

Nickel. In this series three 1 per cent. nickel alloys containing, respectively, 0·01 per cent. of oxygen and 0·005 and 0·013 per cent. of carbon were studied, in addition to the series of binary alloys containing up to 5 per cent. of nickel with a consistently low level of impurities.

The effect of nickel is shown to be influenced by two factors: the occurrence of grain-boundary weakness in alloys containing 2 per cent. or more of nickel, and the formation, to some extent, of α_2 structure. Even small amounts of carbon and oxygen promote brittle behaviour in iron-nickel alloys, and the influence of nickel in accentuating the embrittling effect of oxygen is suggested as a cause of the occurrence of intergranular weakness in alloys containing 2 per cent. or more of nickel. Evidence is presented to show that the brittle strength of iron-nickel alloys probably decreases with rise in temperature.

Chromium and Molybdenum were found to exert only a small effect in reducing the impact-transition temperature of high-purity iron.

Comparison of the influence of silicon, nickel, chromium, molybdenum, and manganese, on the strength of high-purity iron in the ductile condition, shows that the strengthening effect of these elements, for a given weight percentage, increases in the order chromium, molybdenum, nickel, manganese, silicon. Factors which may be involved in the strengthening produced by such additions present in solid solution are discussed, but it is suggested that a more precise knowledge of the particular type of lattice distortion involved is essential for complete elucidation of the mechanism of the strengthening effect.

Magnetostriction in Ferromagnetic Nickel-containing Materials

G. T. RADO: 'Some Magnetostriction Relations in Materials Possessing Preferred Domain Orientations.' *Jnl. Applied Physics*, 1954, vol. 25, Jan., pp. 102-6.

In order to obtain certain properties in ferromagnetic materials it is in some cases necessary to establish a preferred axis in the distribution of domain orientations. Such properties include a high remanence in magnetically hard materials used for permanent magnets, and a rectangular hysteresis loop in magnetically soft materials employed in special transformer cores. Treatments used to establish a preferred axis include subjecting the material to an external stress, annealing in a magnetic field, and orienting the crystallites of the material. In a given material, an analysis of magnetostriction measurements is one possible method for obtaining information on the distribution of domain orientations, but this method appears not to have been adequately exploited. The authors of this paper present a simple but precise formulation of the magnetostriction equation required for such an analysis: it leads to magnetostriction relations to which attention has not previously been drawn. Good agreement with experimental results is obtained. Materials studied in the establishment of the information given include nickel, 50-50 nickel-iron alloy, nickel-aluminium-cobalt-iron-base magnet alloy, a 68 per cent. nickel Permalloy, and iron-aluminium and iron-cobalt alloys.

Measurement of Magnetostriction in Nickel Alloys

See abstract on p. 102.

Ageing Phenomena in Magnet Alloys

K. KRONENBERG: 'Investigations on Ageing Phenomena in Permanent Magnets.' *Zeitsch. f. angewandte Physik*, 1953, vol. 50, Sept., pp. 321-9.

The work reported is closely associated with that referred to in *Archiv. f.d. Eisenhüttenwesen*, 1953, vol. 24, Sept.-Oct., pp. 441-6; see *Nickel Bulletin*, 1954, vol. 27, No. 2, p. 27.

CAST IRON

Magnetic and Electrical Properties of Cast Iron: Reference Data

M. H. HILLMAN: 'The Magnetic and Electrical Properties of Cast Iron.'
Brit. Cast Iron Research Assocn. Jnl. of Research and Development, 1954, vol. 5, Apr., pp. 188-248.

The use of cast iron in engineering applications in which its magnetic properties are significant has been severely restricted in the past due to the absence of any comprehensive collection of data correlating magnetic properties with metallurgical characteristics. The object of the investigation covered by this comprehensive report was to collect the scattered information already available, and to make an original investigation of the magnetic and electrical properties

of a large number of different types of cast iron having varying combinations of graphite and matrix structures. In the experimental section of the work remanent magnetism, coercive force, hysteresis loss, maximum permeability, and specific resistance were determined for twenty-four specimens of cast iron. For each of these an illustration of the microstructure is given in the report, together with the appropriate magnetization curve and hysteresis loop. Details of composition, as determined by chemical and spectrographic analysis, are also included.

The report opens with a useful glossary of magnetic terms: the second section makes a summary of previous work in this field (supported by 26 references to the literature), and the third and major portion is concerned with the work carried out in the laboratory of the British Cast Iron Research Association.

The cast irons for which information is given are of the following types:—

(1) Irons having very coarse flake graphite (A.S.T.M. 1A), ranging through to irons having very fine undercooled graphite (A.S.T.M. 7D) and irons having nodular and aggregate graphite.
(2) Irons having pearlitic, ferritic, and austenitic matrices.
(3) Irons having phosphorus contents ranging from 0·02 to 1 per cent.
(4) Irons having silicon contents ranging from 0·6 to 3·4 per cent.

Some types of low- and high-nickel alloy cast iron are included in the survey.

Ni-Hard Cast Iron: Reference Data

INTERNATIONAL NICKEL CO., INC.: 'Engineering Properties and Applications of Ni-Hard.' * 3rd edn., 1954; 55 pp.

This extensively revised and expanded publication reviews the latest developments and uses of abrasion-resisting cast irons of which the compositions are shown below:—

	Type 1 Regular Ni-Hard	*Type 2 Hi-Strength Ni-Hard*
T.C. % ..	3·00—3·60	2·90 max.
G.C. % ..	0·10 max.	0·10 max.
Si % ..	0·40—0·70*	0·40—0·70†
Mn % ..	0·40—0·70	0·40—0·70
S % ..	0·15 max.	0·15 max.
P % ..	0·40 max.	0·40 max.
Ni % ..	4·00—4·75	4·00—4·75
Cr % ..	1·40—3·50	1·40—3·50

† Silicon content may exceed 0·70% in light-section castings or grey-iron backed castings.

Production, treatment, and properties of these irons are discussed in detail, as influencing their suitability for various applications. The major part of the publication comprises a review of the uses of Ni-Hard castings in the following industries:—cement, ceramic, coal and coke, constructional engineering, dredging, feed and food, handling of industrial minerals, metal-working, mining, paint, petroleum, power, pulp and paper. The descriptive letterpress, which is highly detailed with regard to individual applications in the fields mentioned, is profusely illustrated.

* *We shall be pleased to supply a free copy of this publication.*

CONSTRUCTIONAL STEELS

Segregation Phenomena in Nickel and Chromium-Nickel Steels

K JANSSEN, E. HOUDREMONT and W. JELLINGHAUS: 'Segregation Phenomena in Nickel Steels.' *Archiv f.d. Eisenhüttenwesen*, 1953, vol. 24, July-Aug., pp. 323-32.

After a brief introductory discussion of segregation during solidification, the authors urge the need for a closer understanding of segregation effects occurring in the solid state, e.g., during heat-treatment.

To this end a magnetic and structural study was made of the behaviour of an iron-nickel alloy and two nickel steels after various heat-treatments: the carbon-free alloy contained 6·6 per cent. of nickel; the nickel steels were of the following types: (*a*) carbon 0·3, nickel 5·01, per cent., (*b*) carbon 0·28, nickel 7·00, per cent.

The results of the investigation show that the steels examined provide an example of segregation phenomena occurring without participation of a liquid phase, during incomplete transformation in the solid state. Segregation intentionally produced in the specimens investigated was clearly visible in the microstructures; formation of small amounts of austenite on prolonged heating in the range 550°–650°C. was particularly noticeable. The observations made indicate that a closer investigation of segregation liable to occur during transformations in the solid state is desirable, in connexion, for example, with the heat-treatment of nickel steels of the 5 and 7 per cent. type.

W. JELLINGHAUS: 'Segregation Phenomena in a Chromium-Nickel Steel containing 3·5 per cent. Nickel.' *ibid.*, 1954, vol. 25, Mar.-Apr., pp. 165–7.

This paper reports an extension of the work described in the previous abstract. The steel studied contained carbon 0·15, chromium 1·1, nickel 4·6, per cent. Segregation was produced by selected heat-treatments in the range 620°–690°C. and the steels were examined by magnetic and microscopical methods. The influence of segregation on mechanical properties was also examined.

Spectrochemical Control in Steel Production

See abstract on p. 117.

Formation of Martensite in Austenitic Chromium-Nickel Steels

See abstract on p. 117.

Deformation of Austenite in Nickel-Iron Alloy during Martensitic Transformation

See abstract on p. 111.

Transformations in Nickel-Iron and Nickel-Iron-Carbon Alloys

See abstract on p. 111.

Quantitative Assessment of Temper Embrittlement

N. BROWN: 'A Quantitative Measure of Temper Embrittlement.' *Jnl. of Metals*, 1954, vol. 6, Mar., *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 361–5.

Studies of temper embrittlement have been made from various standpoints (the kinetics of the reaction, change in mechanical properties associated with embrittlement, structural changes accompanying embrittlement, electrical resistivity in relation to the brittle state, etc.). In all the investigations, however, difference in impact properties has been used as the basis of comparison of tough and embrittled material. Recently common agreement has developed that it is preferable to take the difference in transition temperature as a measure of the degree of embrittlement, and this criterion is used in the tests reported in the present paper.

The material used was a steel of the following composition:— carbon 0·13, silicon 0·25, manganese 0·5, sulphur 0·026, phosphorus 0·012, nickel 4·2, chromium 1·3, molybdenum 0·02, aluminium 0·02, per cent. The steel was austenitized at 910°C. for one hour and water-quenched. The as-quenched structure was 100 per cent. martensite throughout $\frac{9}{16}$ in. rods and the hardness was 39–41 Rockwell C. Tempering treatments were at 650° ± 3°C. for two hours: all specimens were divided into four groups, in order to produce various degrees of embrittlement: (1) received no further treatment; (2) 2–3 hours at 525°C., water-quenched; (3) 3 hours at 525°C., water-quenched; (4) 47 hours at 525°C., water-quenched. The transition temperature of the steel was measured in each condition.

From the results reported the author concludes that

(1) the essential difference between the embrittled and the unembrittled state lies in the stress required to produce brittle fracture;
(2) the difference in the reciprocals of the transition temperatures is an invariant with respect to the method of test;
(3) the simple difference in transition temperatures is not an invariant measure of the difference between the embrittled and the unembrittled states.

Determination of Case Depth in Steels

H. MÜLLER: 'Determination of the Depth of Case in Case-Hardening Steels.' *Archiv f.d. Eisenhüttenwesen*, 1954, vol. 25, Mar., pp. 125–31; disc., pp. 131–5.

Critical examination of the various methods for assessment of case depth. The steels used comprised typical case-hardening compositions, including a 2–2 per cent. nickel-chromium grade.

Nickel-containing Steel in P. & O. Liner 'Arcadia'

See abstract on p. 119.

Hard-Surfacing Metallic Materials for use in the Ceramic Industry

See abstract on p. 116.

HEAT- AND CORROSION-RESISTING MATERIALS

Investment Casting of Nickel-Chromium-base Alloys

D. G. McCULLOUGH, F. J. WEBBERE and R. F. THOMSON: 'A Technique for Improving Quality of Investment Castings.' *Amer. Foundrymen's Soc., Preprint* 54–37, May 1954; 6 pp.

The paper describes a method developed by General Motors Corporation for application of the technique of casting water in transparent moulds for study of flow in metal casting. The work was done in connexion with the investment casting of gas-turbine blades from an alloy designated GMR-235, which is stated to have the following composition: carbon 0·15, manganese less than 0·10, silicon less than 0·60, chromium 15·5, molybdenum 5·25, iron 10·0, aluminium 3·0, titanium 2·0, boron 0·075, per cent., nickel balance.

Elevated-Temperature Properties of Steels containing Chromium and Molybdenum

W. F. SIMMONS and H. C. CROSS: 'Report on the Elevated-Temperature Properties of Chromium-Molybdenum Steels.'
Amer. Soc. Testing Materials, Special Tech. Publn. 151, Oct., 1953; 208 pp.

This report is the second in a series of compilations issued under the auspices of the Data and Publications Panel of the A.S.M.E./A.S.T.M. Joint Committee on Effect of Temperature on the Properties of Metals. (The first report, issued in 1938, as Special Technical Publication 124, covered the properties of a large number of commercial stainless steels: see *Nickel Bulletin*, 1938, vol. 11, No. 11, p. 237.)

The present report comprises a graphical summary of high-temperature data for a wide range of steels of varying chromium: molybdenum ratio. It includes information on chromium-molybdenum steels containing small amounts of other elements, e.g., nickel, silicon, titanium, vanadium.

Oxidation Characteristics of Nickel-Chromium Alloys

E. A. GULBRANSEN and K. F. ANDREW: 'Rate of Oxidation of Three Nickel-Chromium Heater Alloys between 500° and 900°C.'
Jnl. Electrochemical Soc., 1954, vol. 101, Apr., pp. 163–70.

Although nickel-chromium alloys have for many years been well known for their high resistance to oxidation, much progress has been made during the past 30 years in improving their behaviour under cyclic operation. Considerable lengthening of life has been achieved by modification in the manganese and silicon content of the alloys, and by addition of small amounts of zirconium, calcium, aluminium, cerium, and other elements. In spite of the technical significance of these improvements, however, no adequate theoretical explanation of the operating mechanism of the improvement has yet been put forward.

Extensive investigations on this subject have been in hand for several years in the Westinghouse Research Laboratories, and a recent series of papers from that source has reported a systematic study (by X-ray and electron diffraction methods) of the crystal structures of oxide films formed on eight alloys of nominal 80 per cent. nickel, 20 per cent. chromium composition. (For the earlier papers see *Trans. Amer. Inst. Min. Met. Eng.*, 1949, vol. 180, p. 519; *ibid.*, 1950, vol. 188, p. 995 and *Ind. Engg. Chem.*, 1953, vol. 45, p. 1734: abstracts in *Nickel Bulletin*, 1949, vol. 22, No. 3, p. 48; 1950, vol. 23, No. 10, p. 188; 1953, vol. 26, Nos. 8-9, p. 147.) It has been shown that in manganese-containing alloys the crystal structures of the films are a function of time and temperature of oxidation, and of the composition of the alloy. In that series of alloys there appears to be no direct correlation between performance in cyclic oxidation tests and the composition and crystal structure of the oxide film.

In the work reported in the present paper rates of oxidation of three alloys of 80-20 nickel-chromium type were studied over the range 500°-950°C. The exact compositions are shown in the table below.

Nickel-Chromium Alloys: Composition and Life Tests

Alloy	Composition %										Useful Life (hr.)	Test Temp. °C.
	C	Mn	Si	Cr	Ni	Fe	Zr	Ca	Mg	Al		
1	0·08	0·01	1·39	19·91	Bal.	0·34	0·10	0·024	—	0·07	157	1175
2	0·08	0·01	0·30	19·98	Bal.	0·32	0·05	0·029	—	0·08	86	
3	0·12	1·70	0·30	19·98	Bal.	0·20	—	—	0·006	—	25	

An oxygen pressure of 7·6 cm. of mercury was used in all the experiments, and the measurements were made by the vacuum microbalance method described in earlier papers of the series. In all tests below 850°C. temper-colour films were obtained, while at and above that temperature grey or grey-green films were developed. No evidence of scaling or cracking of the oxide from the alloys on cooling was found in any tests up to 950°C.

In application of the parabolic law to the data reasonable agreement was found for temperatures above 650°C., but below this temperature the parabolic rate law constant varied with time. This time-variation is explained in terms of changes in composition of the oxide and increase in size of the oxide crystallites.

The classical theory of diffusion is used to interpret observed effects of temperature on rate of oxidation: heats, entropies and free energies of activation for the overall reaction are evaluated from the data obtained. Heats of activation were found to vary from 38,150 cal./mole for alloy 1 in the table to 51,400 cal./mole for alloy 3, while the entropies of activation ranged from −15·8 entropy units (e.u.) for alloy 1 to −3·5 e.u. for alloy 3. On an absolute basis, alloy 2 showed the slowest rate of attack by oxygen under the conditions used, whereas on the basis of the results of A.S.T.M. life tests alloy 1 was superior. As a comparative gauge, chromium reacted with oxygen 4·1 times as fast as alloy 3 and nickel 12·6 times as fast.

Calculations were made on the entropy of vacancy formation, assuming that the reaction follows a mechanism of positive-ion diffusion through vacancies created by the solution of oxygen at the oxide-gas interface. This gives an entropy term of −7·5 e.u., which partially accounts for the negative entropy of activation observed. Agreement of the theoretical rate of reactions with experimental observation was within a factor of 10 for all three alloys.

Nickel-Magnesia High-Temperature Coatings

A. PECHMAN: 'Two New High-Temperature Coatings.' *Materials and Methods*, 1954, vol. 39, Apr., pp. 94-6.

The Ryan Aeronautical Company has recently developed a method of flame-spraying of a nickel-magnesia coating which, it is claimed, gives protection at temperatures up to 3500°F. (1927°C.).

Due to the high fusing temperature of the cermet mixture it cannot be applied to metal surfaces in ordinary furnaces: moreover, the basis materials to which the coating is applied would be impaired by being subjected to temperatures of the order which would be necessary. Flame spraying overcomes these obstacles. By this procedure the nickel-magnesia powder is placed in a metal container attached to the flame-spraying gun and is forced by a stream of nitrogen into the nozzle of the torch. Oxygen and acetylene are also piped to the nozzle, where they burn at a temperature of 5500°F. (3038°C.). As the cermet mixture flows through the flame it liquifies, and is sprayed onto the metal surface, where it cools, solidifies, and adheres, forming a refractory coating, which can be regulated to the required thickness, e.g., 0·001-0·020 in. By this means the coating is deposited without heating the basis metal to temperatures sufficiently high to cause warping or buckling.

It is anticipated that the use of such refractory protection will considerably extend the useful range of service temperature for a number of components, e.g., combustion chambers, and exhaust systems.

The author also makes a report on experience with ceramic coatings of another type developed by the U.S. National Bureau of Standards, which have been under test on stainless-steel exhaust-system components.

Nickel-Magnesia Cermets

See abstract on p. 111.

Nickel Alloys in Marine Engineering

L. B. PFEIL: 'New Metals in Engineering.' *Inst. Marine Engineers*, Advance Copy, Apr., 1954; 6 pp.

The author reviews some materials which have recently become important in marine engineering. The scope of the paper is indicated below:—

(1) *Cast Copper-base Alloys.* This section of the review deals mainly with the influence of section size on the mechanical properties of cast copper-base alloys: attention is directed to some of the newer compositions in which properties in varying sections can be maintained at a more uniform level than is possible, for example, in 85-5-5-5 gunmetal. Particular reference is made to alloys containing copper 88, tin 5, nickel 5, zinc 2 per cent., and to high-tensile aluminium bronzes, of which a typical composition is copper 81·5, aluminium 8·5, nickel 5, iron 5, per cent. The value of some of the newer copper-base alloys in marine propellers is emphasized.

(2) *Graphitic Nickel.* With the advent of higher steam temperatures some of the leaded nickel bronzes which have previously given good service in the marine field are proving inadequate, but it is essential that any material introduced as a substitute for such alloys should provide the good galling-resistance characteristic of the leaded bronzes, and that it should be satisfactorily resistant to corrosion. In this connexion attention is directed to a nickel-base alloy in which advantage has been taken of the known lubricating qualities of graphite, and in which, in order to ensure improved mechanical properties, the graphite is modified to the spheroidal form by the addition of magnesium. A typical alloy contains carbon 1-2·5, silicon 2, manganese 1·5, per cent., with magnesium 0·05-0·15 per cent. in excess of any sulphur which may be present, balance nickel. Some account of these alloys, and of alloys of the same basic type modified by addition of tin, was given in *Trans. Amer. Foundrymen's Soc.*, 1953, vol. 61, pp. 522-9; see *Nickel Bulletin*, 1954, vol. 27, No. 2, p. 26.

(3) *Modified Cupro-Nickel Alloys.* In this connexion the author directs attention to the comprehensive paper on condenser-tube materials presented by GILBERT before the Institute of Marine Engineers in November, 1953 and associated discussion (*Nickel Bulletin*, 1954, vol. 27, No. 2, p. 37). Indications are that the iron-containing 70-30 cupro-nickel will continue to be the most suitable alloy for conditions of particular severity, and that the lower-nickel alloys are also finding useful application in the marine field.

(4) *Spheroidal-Graphite Cast Iron (S.G. Iron).* The widened scope of application opened to cast iron by the introduction of the spheroidal-graphite type is discussed, with particular reference to the suitability of the new material for marine uses. Some properties typical of S.G. iron are compared with those characteristic of flake-graphite irons and of cast steel, and some marine engineering parts for which S.G. iron is already being used are illustrated. The acceptability of S.G. iron in this field is already demonstrated by its adoption, under varying conditions, by U.S., Continental and British standardizing authorities.

(5) *Heat-Resisting Materials.* The interest of the shipping world in the use of gas-turbine propulsion, and the development of the gas turbine for industrial applications on land have brought in their train problems with regard to methods for evaluating high-temperature materials for long-term service. Some difficulties inherent in accelerated testing are considered by the author, and the nature of the deterioration which may occur at high temperatures, by creep, fatigue, or corrosion is discussed, on the basis of observations made on typical high-temperature alloys. Attention is directed to the problem of corrosion by vanadium pentoxide and other compounds occurring in gas turbines operating on fuel oil. Reference is made to research which has been carried out to determine the influence of composition of the alloys on resistance to corrosion, and to proposals which have been made for treatment of the oil fuel with preventive media. In connexion with the possibility of using cooled blades as a means of lowering the operating temperature of the critical components, an account is given of experiments on the production of hollow blading by extrusion. The introduction of this method of fabrication has opened up a wide field for further development, and is likely to permit the use, for gas-turbine blading, of alloy compositions which will withstand conditions more severe than those currently employed.

(6) *Hard-Surfacing Materials.* A relatively recent development which appears to have far-reaching practical interest in the marine and other engineering fields is the use of hard-surfacing with materials capable of withstanding corrosive, erosive, and high-temperature conditions. The nickel-chromium-boron alloys are especially important in this connexion. Vis-à-vis alloys of the Stellite (cobalt-chromium-base) type they can be more easily applied (melting point of the nickel-base alloys is 1050°C., as compared with 1175°C. for typical Stellite alloys), and the nickel alloys are much more fluid, with the result that they can be deposited, by spray-welding methods, to very close tolerances and with a very smooth surface. Application is normally effected by spray gun, using alloy powder direct or an extruded plastic wire incorporating the powder, and the sprayed deposit is subsequently fused by oxy-acetylene torch.

Hard-Surfacing Metallic Materials for Use in the Ceramic Industry

W. L. LUTES and H. F. REID: 'Hard-Facing in Ceramic Industries.' *Amer. Ceramic Soc. Bull.*, 1954, vol. 33, Mar., pp. 79-82.

Hard-facing has for many years been recognized as a standard maintenance procedure for extending the life of equipment subjected to many types of wear, and some parts of heavy equipment are now hard-surfaced before being put into service. Despite this general acceptance of the practical value of the method, no general standards have been formulated for evaluating the properties and spheres of application of the

various surfacing materials in commercial production. For the past two years, however, a joint committee of the American Welding Society and the American Society for Testing Materials has been working towards the drafting of a specification for hard-facing filler materials.

The present paper is designed to bring to the notice of those working in the ceramic industry recent developments in hard-facing materials and methods, and to point out certain advantages which may result from an understanding of some of the factors involved in wear, as a basis for selection of the correct electrode for hard-surfacing parts used in specific applications. A list is given of hard-facing materials of various types, arranged in a classification proposed by the joint committee in 1950, and in a second table these materials are comparatively rated according to hardness, general atmospheric-corrosion resistance, resistance to abrasion by earth, resistance to deformation at elevated temperatures, service under heavily abrasive conditions, and service involving sliding and rolling wear. On the basis of these ratings, suggestions are made for application of the respective hard-facing materials on components employed in the ceramic industries. Among the materials evaluated are low-, medium-, and high-alloy steels (including nickel-containing types), austenitic alloy cast irons, and nickel-base alloys of the nickel-copper, nickel-chromium, and nickel-molybdenum-chromium-tungsten types.

Prevention of Cracking in Austenitic Weld Metals

H. F. TREMLETT: 'Cracking in Stainless and Heat-Resisting Weld Metals.' *Trans. Inst. Welding*, 1953, vol. 16, Dec., pp. 143–50; disc., pp. 150–3.

The theme of the paper is the possibility of preventing cracking in high-alloy weld metal by correct choice of structure. If the structure is fully austenitic there is a marked tendency to development of cracks: if the composition of the weld metal is altered in such a manner as to introduce a small amount of ferrite, crack-susceptibility is virtually eliminated. To demonstrate the benefits of this procedure, typical laboratory crack-test results are given on welds in various types of corrosion- and heat-resisting materials.

The writer counters the opposition which has been raised to the use of duplex weld metal (on the grounds of conversion of the ferrite, at high temperatures, into austenite and sigma phase) by the following statement:—

'Experiments which are not reported in this paper have shown that a fully austenitic weld structure on heating breaks down to austenite and carbide, producing a degree of embrittlement which is not greatly different from that produced by the development of austenite and sigma from ferrite. This may be explained by the different mode of distribution of the brittle phases in the two types of weld deposit. The duplex weld metal, which consists of austenite and randomly dispersed ferrite in the as-deposited condition, becomes, after service at the working temperature, a random dispersion of sigma and carbide in austenite. The austenitic weld metal, after heating, becomes austenite with carbide or carbide and sigma at the grain boundaries. The greater embrittling effect of brittle phases (carbide and sigma) at the grain boundaries has been demonstrated by treating a 25 Cr–15 Ni steel so as to produce, on the one hand, randomly dispersed carbide and sigma and, on the other, grain-boundary carbide and sigma. In an impact test, the specimens in the latter condition absorbed only a third as much energy as those in the other condition.

'Thus the contention that the austenitic weld metal should be preferred as being free from embrittlement in service is not well supported. Accepting an approximately equal degree of embrittlement in the duplex and austenitic welds, the advantage from the practical point of view lies with the duplex type, in their lesser susceptibility to cracking.'

Spectrochemical Control in Stainless-Steel Production

H. C. BROWN: 'Application of the A.R.L. Quantometer to Production Control in a Steel Mill.' *Jnl. of Metals*, 1954, vol. 6, Mar.; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1954, vol. 200, pp. 349–52.

The paper describes the use of the Applied Research Laboratories' Production Control Quantometer in the quantitative control of stainless, silicon, and plain-carbon steels, in the plant of the Butler Pennsylvania Division of Armco Steel Corporation. In general, the quantometer determines all elements necessary for regulating the composition of all types of stainless-steel heats, and is also suitable for the ladle analysis of various types of stainless steel. In addition, it is used in these works in reporting final results for silicon, manganese, chromium, nickel, molybdenum, tin, and copper residuals on several plain carbon steels. A table in the paper shows the elements for which the instrument can be used and the concentration ranges over which determinations can so be made. Typical results obtained on ladle test samples of various types of chromium and chromium-nickel stainless steels are individually discussed, also determinations on silicon steels. It is found that in regular production the use of the quantometer permits substantial saving of manpower and time.

Formation of Martensite in Austenitic Chromium-Nickel Steels

T. ANGEL: 'Formation of Martensite in Austenitic Stainless Steels. Effects of Deformation, Temperature and Composition.' *Jnl. Iron and Steel Inst.*, 1954, vol. 177, May, pp. 165–74.

This paper reports study of the isothermal formation of martensite induced by plastic deformation in austenitic stainless steels in the temperature range −188° to +100°C. The material used was taken from 18-8 chromium-nickel steels of types currently produced in Sweden.

Conclusions

The results reported are in agreement with the reaction-path theory of the martensitic transformation

advanced by Cohen. Deformation of martensite is regarded as competing with the slip mode of deformation.

The governing factor in the formation of martensite induced by deformation is considered to be the supply of mechanical energy through deformation. Stress is here of primary importance, since deformation is shown to be only a consequence of the formation of martensite caused by the action of stress. Strain, either as a result of the martensite or the slip mode of deformation, is, however, assumed to be of some importance, because it affects the stress conditions, so that local peaks of stress may be formed, activating some martensite embryos.

The influence of temperature is discussed in terms of the relation between the martensite and the slip mode of deformation: the main transition between the two modes of transformation was found to take place within a narrow range of temperature.

Contrary to views expressed in earlier literature, the authors conclude that, in the martensite transformation, chromium, silicon and molybdenum act as stabilizers of austenite, as do nickel, manganese, carbon and nitrogen.

Shell-Moulding of Stainless Steel

'Casting Stainless Steel and Other Alloys in Shell Moulds. Methods employed by Langley Alloys, Ltd.' *Machinery* (*Lond.*), 1954, vol. 84, Apr. 23, pp. 853–61.

Reference was made in an earlier issue of this journal to the shell-moulding of 18-8-3 chromium-nickel-molybdenum steel valves in the foundry of Langley Alloys, Ltd., Slough: see *Nickel Bulletin*, 1953, vol. 26, No. 12, p. 214. Since the publication of that article the use of the shell-moulding process has been extended to the production of other castings. These later developments are now reviewed.

The first part of the article contains an illustrated description of equipment of an improved type which has been evolved from that used in the earlier stages of the shell-moulding development, and this is followed by notes on some typical castings produced. Alloys being used for such castings include the range of Langalloy alloys (nickel-molybdenum and nickel-silicon-base alloys), Monel, stainless steels of various types, aluminium- and manganese-bronzes, and gunmetal.

Extrusion of Stainless and Heat-Resisting Steels

E. C. BEAUDET: 'Allegheny Ludlum Hot Extrudes Stainless, High-Alloy Steels.' *Iron Age*, 1954, vol. 173, Mar. 25, pp. 137–40.

The article describes plant and practice at the Watervliet plant of Allegheny-Ludlum Steel Corporation, where tubing and shapes of stainless and heat-resisting steels are now being extruded on a commercial basis. All the standard chromium-nickel and straight-chromium grades are being handled, and the seamless tubing, $1\frac{5}{8}$–4 in. in diameter and 12–45 ft. long, is produced at rates of 25–30 pushes per hour. In addition to the tube products, which form the bulk of the output, shapes of 0·5–3·0 sq. in. cross-section and 12–60 ft. long are also being made by extrusion. The lubricant used is glass, which serves also to insulate the billet during extrusion.

Manufacture of Stainless-Steel Tubing

'The Manufacture of Small-Diameter and Other Special Precision Tubes.' *Machinery* (*Lond.*), 1954, vol. 84, Mar. 19 and Apr. 2, pp. 575–85; 679–86.

These articles give a detailed and well illustrated description of methods used in the works of Accles and Pollock, Ltd., Oldbury, in production of precision tubing of small size. Particular attention is given to the manufacture of hypodermic-needle tubing and other varieties of tube used in scientific and other high-precision apparatus. For hypodermic needles the Company has developed a special grade of nickel-chromium stainless steel, in which the unusual combination of mechanical properties required is obtained by work-hardening through a planned sequence of operations. For other types of tubing (of which a very wide range is made in these works) the materials used include stainless iron and medium-alloy steels of nickel-containing and other types. Sections of the article deal, respectively, with equipment and methods used in drawing, bright-annealing, pulling to gauge, finish drawing, straightening, and inspection. Some account is also given of practices adopted in preparation and maintenance of drawing dies.

Machining of Stainless Steels: Recommended Procedure

J. D. ARMOUR: 'Guide for Machining Stainless Steels.' *Steel*, 1954, vol. 134, Mar. 22, pp. 92–5; Mar. 29, pp. 106–8, 110.

This article is of an essentially practical type, being based on extensive research and workshop tests carried out by Republic Steel Corporation. In general, successful machining of stainless steels is contingent on the use of:—suitable tool materials (high-speed steel or carbide); sufficient power to maintain constant feeds and speeds; rigid tools, tool-holders, etc.; a good coolant or lubricant adjusted to give an abundant flow at the point of cutting; correct speeds and feeds.

The author gives a number of drawings illustrating tools suitable for the various forms of machining operation, also tables showing cutting speed and feeds appropriate for respective grades of steel. This information is supplemented by other details of recommended practice.

As a means of arriving at the characteristics of the different types of stainless steel, and of the machining conditions which will give best results, the Republic Steel Corporation laboratory makes use of a standard test, carried out in an automatic screw machine which provides information on probable behaviour in ten types of machining operations. The technique of test and method of assessing the results and correlating them with composition and treatment of the steels are explained.

A feature of the second part of the article is a table

showing 'typical troubles' encountered with tools used in cutting stainless steel, with suggestions of the causes of the difficulties and methods for overcoming them. More than 40 individual 'troubles' are considered.

Heat Transfer at Sodium/Stainless-Steel Interface

J. W. MOYER and W. A. RIEMEN: 'Heat-Transfer Measurements at Sodium/Stainless-Steel Interface.' *Jnl. Applied Physics*, 1954, vol. 25, Mar., pp. 400–5.

Experience with mercury boilers has shown that a critical change in the heat-transfer coefficient occurs as the mercury wets the metal container, and it has been believed that a considerable thermal barrier might exist at the interface of stainless steel and liquid sodium when the angle of contact is large. This paper reports measurements of the heat-transfer coefficient at a sodium/austenitic nickel-chromium steel interface, as a function of temperature, over the range 100°–500°C. The results show that wetting does not, in this case, play a significant rôle.

Nickel-containing Materials in P. & O. Liner 'Arcadia'

'The P. & O. Liner 'Arcadia'.' *Engineering*, 1954, vol. 177, Apr. 9 and May 21, pp. 474–5, 662–4.

A description is given of the design of the liner and the accommodation which it provides, also of its machinery, boilers, and equipment. Among the references to materials employed for individual items of plant and equipment the following are noted:— impulse blading in the turbines is throughout of Hecla A.T.V. (nickel-chromium-iron alloy), reaction blading is of Monel or stainless iron. Hecla A.T.V. is used also for the nozzle vanes. Primary pinions in the high-pressure turbine are of nickel steel. Each of the main condensers has a cooling surface of 17,500 sq. ft., and will pass 134,000 lb. of steam per hour. The tubes are of cupro-nickel.

Hydrogen Absorption by Austenitic Steels during Cathodic Loading

F. EISENKOLB and G. EHRLICH: 'Hydrogen Absorption by Austenitic Steels during Cathodic Loading.' *Archiv f.d. Eisenhüttenwesen*, 1954, vol. 25, Mar.-Apr., pp. 187–94.

Although the literature on hydrogen absorption by metals is extensive, relatively little information has been published on the behaviour of austenitic steels at room temperature. In view of the known deleterious effect of hydrogen absorbed during pickling, on the mechanical properties of ferritic steels, it was considered advisable to determine the reactions of other types of steel.

Following a review of relevant literature on cathodic absorption of hydrogen, the authors describe experiments on sheet of the materials shown in the table below.

Change in properties due to hydrogen absorption was assessed by means of reverse-bend tests under standard conditions, tests being made on several specimens in order to allow for the known scatter liable to occur in such tests and to permit averaging to reliable values. The electrolytes used were: 2*N* solutions of sulphuric and hydrochloric acids, and caustic potash, with or without small additions, see (1) below.

The tests were arranged in three series:—

(1) to determine the influence of the electrolyte used, and the conditions of electrolysis. This series included use of acid solutions containing small additions of arsenic, selenium, tellurium, lead, tin, bismuth, antimony, sulphur. Mercury additions were used in the alkaline solution. The effect of concentration of the basis solution, on hydrogen absorption, was also studied, in sulphuric-acid solutions 0·1–10*N*;

(2) to study the influence of the composition of the material electrolysed. In this set of tests a sulphuric-acid solution containing an addition of arsenic was employed. The austenitic steels were

C %	Si %	Mn %	P %	S %	Cr %	Ni %	Thickness mm.
0·17	0·20	0·51	0·025	0·011	16·5	7·6	0·22 (1)
0·11	0·20	0·56	0·018	0·030	16·0	7·8	0·21 (1)
0·05	0·48	0·39	0·012	0·010	17·4	8·5	0·19 (2)
0·05	0·55	—	—	—	—	29·9	0·20 (2)
—	—	—	—	—	—	95·5	0·21 (2)
0·09	0·09	0·42	0·003	0·046	—	—	0·20 (3)

(1) Rolled down from 2 mm. thick with two intermediate annealings and a final annealing at about 1100°C., followed by quenching in water.

(2) Rolled down from 1 mm. thick with one intermediate annealing, and final annealing at 1100°C., followed by quenching in water.

(3) Rolled down from 1 mm. thick with one intermediate annealing and final annealing at about 920°C.

electrolysed in various conditions (heat-treated as shown in Table I; after cold-working to induce breakdown of austenite, after cooling in liquid air; after thermal treatment designed to induce susceptibility to intercrystalline corrosion);

(3) to observe the mechanism of hydrogen diffusion, evolution of hydrogen, and the permanent damage resulting from hydrogen absorption.

The results indicate that, in the conditions used, austenitic steels are capable of absorbing hydrogen, and that those contaminants in the solutions which have proved to accelerate hydrogen absorption by ferritic steels have a similar influence in the case of the austenitic steels. The observations made show that the anion present is determinative with regard to the amount of hydrogen absorbed: the effect was greatest in hydrochloric-acid solutions.

A point of difference between the behaviour of the austenitic steels and that characteristic of ferritic steels is that with the former there is a marked maximum in absorption after moderate times of electrolysis, and that this is associated with maximum embrittlement, as demonstrated by the reverse-bend test. Moreover, in austenitic steel, as in nickel, there is no substantial capacity for diffusion of hydrogen at room temperature.

Although the results of the bend tests leave no doubt that hydrogen absorption occurs in the austenitic steels, there is evidence that most of the gas remains in a thin surface layer, a conclusion which is supported by the fact that after twenty-four hours at room temperature or three hours at 140°C. most of the gas is evolved from the steel and no permanent deterioration in properties appears to result. Hydrogen absorption was intensified in austenitic steel specimens which had been cold-worked to break down the austenite, or heat-treated at 750°C., but by heating these specimens at a relatively low temperature the greater portion of hydrogen could be removed, with associated disappearance of brittleness.

Effect of Potential on Corrosion-Resistance of Nickel-Chromium Steel

C. EDELANU: 'Method for the Study of Corrosion Phenomena.' *Nature*, 1954, vol. 173, Apr. 17, p. 739.

Many metals and alloys show passivity in strong acid solutions, although on thermodynamic grounds their oxides might be expected to be soluble in such solutions. In the stainless steels this 'kinetic' passivity is very clearly marked. This letter describes corrosion experiments made, at constant potentials, on an 18-8 chromium-nickel steel, with the aim of securing a better understanding of the behaviour of such materials in this respect.

Typical results obtained in a 20 per cent. sulphuric-acid solution, at 25°C., show that at high potentials corrosion is rapid, at some intermediate values it is low, subsequently increasing to a maximum as the potential is lowered, and finally at very low potentials decreasing to very small values. Such behaviour can be explained by assuming that the rate of corrosion of oxide-covered metals is controlled by the rate at which the oxide dissolves, which, in turn, depends on the composition of the oxide. Dissolution is rapid at high potentials, where the oxide is presumed to be oxidized beyond its normal stoichiometric composition. Iron, not readily oxidized beyond the trivalent state in acid solution, shows no noticeable increase in rate of corrosion at high potentials, whereas the reverse is true of alloys containing chromium, since under such conditions chromium is more readily oxidizable. The corrosion product at high potential has, indeed, been found to consist mainly of hexavalent chromium, with only traces of the trivalent ion. The range of intermediate potential over which there is no appreciable corrosion corresponds, it is believed, to conditions favouring oxides which have the approximate composition Me_2O_3. It is presumed that at lower potentials, where corrosion again becomes appreciable, the oxides are partially reduced before being dissolved. Final values for corrosion, at the lowest potentials, are considered to represent the conventional anodic polarization curve for the material.

It is pointed out that these assumptions explain many well-known features of the behaviour of stainless steels, such as inhibition of corrosion in sulphuric acid by the presence of copper or other weakly oxidizing ions, which place the potential within the safe intermediate range. The writer points out that the observations made, and the use of the method, can be of value in development of new alloys for specific applications.

A further finding reported from these tests is that even when passivity of stainless steels has fully broken down it can be re-established by suitable anodic polarization, and that the passivity of an 18-8 steel can be maintained even in boiling 50 per cent. sulphuric acid (which would normally cause rapid corrosion) by passing a very small current. It would appear that formation of a new oxide by the reaction of the metal with the solution is possible, even though the oxide is only a metastable phase. The presence of oxygen appears to be unnecessary, in view of the fact that protection has proved to be possible at potentials not high enough for its electrolytic formation, and in solutions de-aerated by constant boiling.

The adaptation of the method as a means of selectively etching two-phase alloys is suggested, since in such materials each phase has a characteristic curve and it is often possible to find some potential at which only one phase is corroded at an appreciable rate. (A fuller account of the work is to be published later.)

Stainless-Steel Bellows

'Automatic Welding Builds 28-ft. Stainless-Steel Bellows.' *Industry and Welding*, 1954, vol. 27, Apr., pp. 44-6, 48, 88-9.

The article describes manufacture, by Solar Aircraft Company, of stainless-steel bellows and expansion joints; the bellows range in diameter from $\frac{5}{8}$ in. to 28 ft. They are of two general types, convoluted and fabricated, the latter being made by forming the steel and welding the convolutions to each other and to

the pipe ends. Some details are given of the welding operations used, and of inspection methods employed to ensure strict control of quality. Some 90 per cent. of the bellows made in the Solar works are of stainless steel; the remainder are principally of Monel.

Chromium-Nickel Steel Tubes for Welding: B.S. Specification

BRIT. STANDARDS INSTN.: 'Chromium-Nickel Heat-Resisting Steel Tubes (Suitable for Welding).' *B.S. Specn. T. 61*, Apr., 1954 (replacing D.T.D. 491).

The composition limits are as shown in the table.

Composition, per cent.

Carbon	0·16 max.
Silicon	0·20 min.
Manganese	1·0 max.
Nickel	16·0-18·0
Chromium	20·0-26·0
Titanium	5 × C min.
or	
Niobium	10 × C min.
Sulphur	0·045 max.
Phosphorus	0·045 max.

Mechanical tests, and the copper-sulphate test for determination of susceptibility to weld decay, are specified.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

THE MOND NICKEL COMPANY LIMITED
SUNDERLAND HOUSE · CURZON STREET · LONDON, W.1

PRINTED IN ENGLAND *by* WIGHTMAN MOUNTAIN LTD.
WESTMINSTER, LONDON, S.W.1